AFRL-HE-WP-TR-2001-0045

UNITED STATES AIR FORCE RESEARCH LABORATORY

Development and Testing of a New Reefing System to Reduce Parachute Opening Shock Characteristics During Seat Ejection

John C. Brinkman

SYSTEMS RESEARCH LABORATORIES
2800 Indian Ripple Road
Dayton OH 45440-3696

November 1992

Final Report for the Period November 1990 to November 1992

20011031 087

Human Effectiveness Directorate
Biodynamics and Protection Divison
Biodynamics and Acceleration Branch
2800 Q Street BLDG 824 RM 206
Wright-Patterson AFB OH 45433-7947

NOTICES

When US Government drawings, specifications of other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Air Force Research Laboratory. Additional copies may be purchased from:

National Technical Information Services
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
8725 John J. Kingman Rd STE 0944
Ft. Belvoir, VA 22060-6218

TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-TR-2001- 0045

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

F. Wesley Bl

F. Wesley Baumgardner
Chief Biodynamics and Protection Division
Human Effectiveness Directorate
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1992	Final - November 1990 to November 1992

4. TITLE AND SUBTITLE

Development and Testing of a New Reefing System to Reduce Parachute Opening Shock Characteristics During Seat Ejection

5. FUNDING NUMBERS

Contract: F33615-89-C-0574
PE: 63231F
PR: 2830
TA: 283068
WU: 28306821

6. AUTHOR(S)

John C. Brinkman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Systems Research Laboratories, Inc.
2800 Indian Ripple Rd.
Dayton, OH

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Human Effectiveness Directorate
Biodynamics and Protection Division
Biodynamics and Acceleration Branch
2800 Q ST BLDG 824 RM 206
Wright-Patterson AFB OH 45433-7947

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-HE-WP-TR-2001-0045

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report summarizes the initial testing of a new parachute slider reefing system to control the opening dynamics of the military C-9 parachute. It has been theorized that if one could control the opening of the parachute canopy used during emergency ejections, the parachute opening forces on the crewmember could be significantly reduced. The report addressed the reefing system modification and summarizes the initial testing results of the new slider reefing system to control the parachute opening dynamics.

14. SUBJECT TERMS

15. NUMBER OF PAGES
5

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UNLIMITED

NSN 7540-01-280-5500
Computer Generated 1996

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

THIS PAGE INTENTIONALLY LEFT BLANK

DEVELOPMENT AND TESTING OF A NEW REEFING SYSTEM TO REDUCE PARACHUTE OPENING SHOCK CHARACTERISTICS DURING SEAT EJECTION

John C. Brinkman
Mechanical Engineer

Systems Research Laboratories, Inc.
2800 Indian Ripple Rd.
Dayton, Ohio

ABSTRACT As the speed of today's aircraft continues to increase, so does the difficulty of returning the pilots safely to the ground. To improve the safety of the pilot during seat ejection, the parachute's deceleration forces need to be reduced. It has been theorized that if one could control the opening of the canopy, the forces seen by the pilot could be significantly reduced. Initial testing has been completed on a new slider reefing system to control the opening dynamics. This paper will address the modification and the acceleration profiles of the new system.

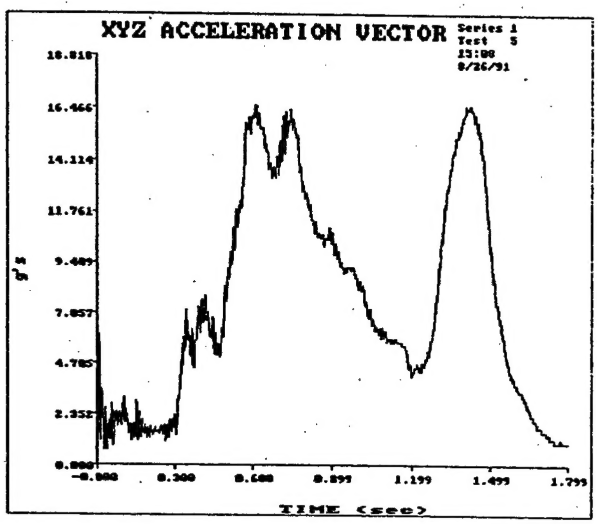
INTRODUCTION To reduce the potential for injury during seat ejection, the opening force characteristics of the C-9 need to be addressed. The task is to reduce the forces by altering the reefing system. In 1972, the present reefing line system with pyrotechnic cutters was implemented to control the opening of the C-9. While the military parachute has remained the same, the sport parachute has changed dramatically. Today's sport parachute is a square, or gliding canopy. The square uses a slider to control the opening dynamics. Because of the mild opening characteristics, the square's are commonly jumped hundreds of times without injury to personnel or equipment. By adapting the technology of sport parachutes to the development of a new reefing system, the opening shock characteristics of the C-9 can be controlled. The slider reefing system will not only reduce the forces during opening, but will eliminate the need for the 11P12-15-7 Reefing Line Cutters.

METHODS When evaluating any modifications to the reefing system, a baseline of the standard ACES II configuration will be referenced. To produce non-biased results, the baseline data and any modification evaluations need to be performed using the same test conditions. To insure similar testing conditions from test to test while maintaining a cost effective means for testing, the Cylindrical Test Vehicle (CTV) has been developed. The CTV is used to evaluate parachute opening shock characteristics with various reefing systems. The developmental testing of the CTV is used to establish the criteria for the base line evaluation. Because of stability problems, the effective air speeds of the test vehicle are limited to 300, 375, and 450 feet per second. To simulate parachute deployment, the CTV deploys the ACES II headbox across the air stream, similar to the ejection seat. An onboard instrumentation system is used to determine effective air speed at deployment, the riser loads, the acceleration vector, and the altitude loss. An onboard camera provides video coverage during deployment.

RESULTS Three tests at the lower speeds and ten at the higher test speed have been completed to produce the baseline for any

modification to the ACES II reefing system. Figure one illustrates a typical acceleration profile for the ACES II reefing system during a high speed deployment.

Figure 1
C-9 with Standard ACES II Reefing System

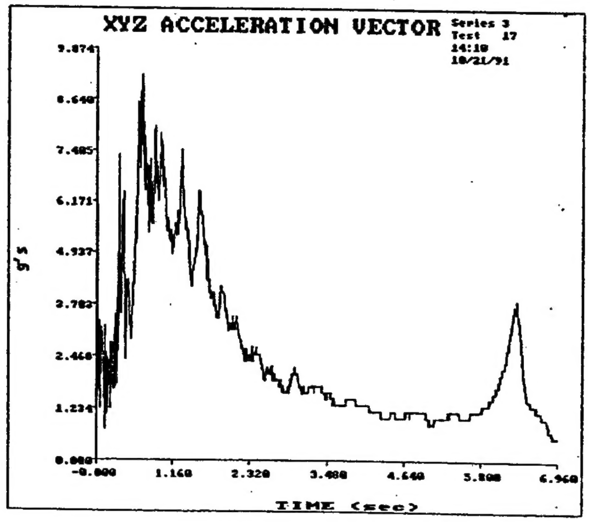


Test condition   Air speed: 450 ft/sec.
CTV weight: 300 lbs.

Note in figure 1, the standard reefing system introduces dynamic pulsing. The energy is distributed into two large pulses. The first pulse averaged 15.9 g's and the second 14.5 g's thru the baseline testing. There are several means to improve the safety of the pilot by altering the general characteristics of the acceleration profile. A more desirable profile would distribute the energy in a single pulse with reduced magnitude while improving the altitude loss factor.

To provide an acceleration profile that will address these features, the reefing system would have to control the rate of the opening based on the tension in the suspension lines. On todays sport rig, the opening is controlled by a square slider. By varying the surface area and the shape of the slider, the sport jumpers can control the rate of the opening. Because of the speed and the nature of the C-9, a square slider may not allow the canopy to open. When adapting a slider to a round canopy, you must allow air to pass thru the slider to inflate the canopy. The new system will eliminate the reefing line, and replace it with a ring slider. The slider will control the opening, by allowing the mouth to open based on the internal pressure differential. As the internal pressure increases, the force to open the mouth will cause the slider to move down the suspension lines. For the initial testing, a slider was constructed using a single 13 foot band around the mouth of the canopy. Seven grommets have been equally spaced around the ring. Four of the twenty eight suspension lines will pass thru each grommet. With the elimination of the slider's surface area, the slider will rely on a pressure differential to control it's position on the suspension lines. Note in figure 2, it is feasible to reduce the amplitude by increasing the duration. Figure 2 illustrates the typical acceleration profile from a high speed deployment with the 13 foot ring slider.

Figure 2
C-9 with 13 Foot Ring Slider

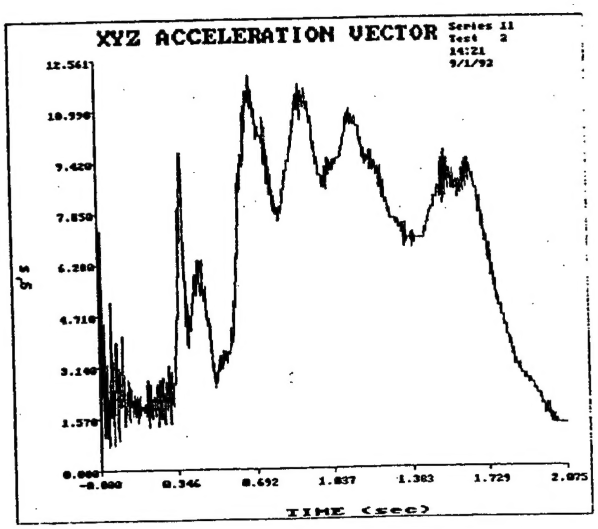


Test conditions   Air speed: 450 ft/sec.
CTV weight: 300 lbs.

The amplitude for the first pulse with the line cutters has been reduced from 15.9 g's to an average of 9.6 g's for the 13 foot ring slider. Although the ring slider has reduced the loads, it has introduced an additional problem. The time interval

between first peak and the steady state descent rate has become unpredictable. By increasing the interval of time, the 13 foot slider has increased the altitude loss required to reach the steady state descent rate. To improve the general characteristics of the acceleration profile the time interval needs to be reduced. To reduce the interval from mortar fire to a full open condition, the size of the slider will be increased until a desirable profile is reached. Additional testing has been completed using a longer ring slider. The length of the slider has increased in fourteen inch increments until the slider reached the length of 21 feet. These tests were conducted to reduce the time interval between mortar fire and a steady state decent rate. Figure 3 illustrates the typical acceleration profile from a high speed deployment with the 21 foot ring slider.

Figure 3
C-9 with 21 Foot Ring Slider



Test conditions Air speed: 450 ft/sec.
CTV weight: 300 lbs.

Note in figure 3, the energy has been removed in a large pulse. The maximum g loads have been kept to 12 g's and the duration of the pulse has been increased. The 21 foot ring slider also reached the steady state decent rate while losing only 1000 feet of altitude from the time of deployment. This is comparable to the average 1020 foot loss by the standard ACES II system.

Conclusion As the results of the test disclosed, the ring slider can reliably control the opening. Additional tests will be conducted to determine the effects of the ring slider as the size continues to increase. The length of the slider will be increased until it adversely effects the opening dynamics. At this point, the initial testing of the ring slider reefing system will be completed.

ACKNOWLEDGMENTS The author wishes to thank Stephen Mehaffie, Todd Mosher, Jim Bolton, Jeff Logan, Monty Crabill, and Steve Bolia for their technical support.

Work sponsored by CREST Program under
Contract No. F33615-89-C-0574
Deputy Program Manager
Stephen R. Mehaffie

Armstrong Aerospace Medical Research Laboratories
Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base
OH 45433-6573